# Analysis of Aircraft for the Fire Fighting Mission in Colorado

Prepared for

Senator Steve King

Prepared by

Conklin & de Decker Aviation Information

December 6, 2013

COLORADO FIREFIGHTING AIR CORPS

Conklin & de Decker
Aviation Information

**Analysis of the Alenia C-27J, British Aerospace 146-200, Lockheed S-3B and Lockheed C-130H/Q Aircraft for the Fire Fighting Mission in Colorado.**

December 6, 2013

Prepared by:

Conklin & de Decker Aviation Information
Arlington, TX 76012
817 277 6403
www.conklindd.com

**Table of Contents** **Page**

# 1 Summary and Conclusions

The State of Colorado is analyzing the effectiveness of commercially available makes and models of Type 1 and Type 2 aircraft to fight wildland fires in the state. Four aircraft have been identified as potentially meeting the state's requirements:

| *Make and Model* | *Type* | *Status* |
|---|---|---|
| • Lockheed C-130H/Q | 1 | On "Next Gen" contract with USFS |
| • British Aerospace BAe-146 | 1 | On contract with USFS |
| • Alenia C-27J | 2 | Storage at Davis Monthan AFB |
| • Lockheed S-3B | 2 | Storage at Davis Monthan AFB |

A detailed study was conducted to examine these four aircraft and analyze their capabilities in four primary areas, as summarized below.

- Retardant tank volume (certificated or estimated)

The Lockheed C130H/Q has the largest tank (3,500 gallon), is certificated and in service with the US Forest Service on a "Next Gen" contract. The BAe 146, with a 3,000 gallon tank, is also certificated and in service with the US Forest Service. The tank volume for the Alenia C-27J and Lockheed S-3B are estimated to be significantly less than 2,000 gallon.

| | | *Tank Volume* | *Comments* |
|---|---|---|---|
| Lockheed | C-130H/Q | 3,500 Gal. | Certificated |
| British Aerospace | BAe 146-200 | 3,000 | Certificated |
| Alenia | C-27J | 1,850 | Preliminary Estimate |
| Lockheed | S-3B | 1,607 | Preliminary Estimate |

- Mission payload capability from USFS air tanker bases in Colorado

The Lockheed C-130H/Q has by far the best mission payload capability when taking into account not only tank size but also take off runway requirements and engine-out climb requirements at the four existing Colorado fire fighting Air Attack Bases during typical summer temperatures (ISA + 30 degrees C).

| | | *C-27J* | *BAe 146* | *S-3B* | *C-130H/Q* |
|---|---|---|---|---|---|
| Denver | BJC | 142 | 1,804 | 157 | 3,500 |
| Durango | DRO | 13 | 1,568 | 31 | 3,500 |
| Grand Junction | GJT | 279 | 1,993 | 259 | 3,500 |
| Pueblo | PUB | 301 | 2,009 | 276 | 3,500 |
| Average | | 184 | 1,844 | 181 | 3,500 |

- Sustainability and after sales product support

Sustainability is a direct function of the production status of the aircraft as well as the number of aircraft in service in the US. In addition, for fire fighting aircraft, compliance with NTSB A04-029 and retardant tank certification are important factors. The analysis summarized below ranks each aircraft on a scale from 1 to 4 for each item.

| | *C27J* | *S3B* | *BAe 146* | *C130H/Q* |
|---|---|---|---|---|
| Production Status | 1 | 4 | 4 | 2 |
| In Service Fleet | 3 | 4 | 5 | 1 |
| NTSB A04-029 | 4 | 4 | 1 | 1 |
| Tank Status | 3 | 4 | 1 | 1 |
| Composite Score | 11 | 16 | 11 | 5 |
| | | | | |
| Ranking | 2 | 4 | 2 | 1 |

This shows that the Lockheed C-130H/Q has the best sustainability ranking, followed by the BAe 146 and the Alenia C-27J. The Lockheed S-3B ranks last.

- Mission effectiveness expressed as gallons transported per hour and per day

Two effectiveness measures were examined. The first was the average number of gallons of retardant delivered per hour to a fire anywhere in the state

*Aircraft Retardant Delivery Capability per Hour*

| | | *C 27J* | *BAe 146* | *S-3B* | *C 130H/Q* |
|---|---|---|---|---|---|
| Gallons per Hour | GPH | 126 | 1,317 | 139 | 2,211 |

The second was the average total number of gallons delivered per aircraft after five flights.

*Retardant Delivered by One Aircraft with 5 Flights (Gallons at ISA + 30 deg C)*

| | | *C-27J* | *BAe 146* | *S-3B* | *C-130H/Q* |
|---|---|---|---|---|---|
| Average Gallons | | 919 | 9,218 | 904 | 17,500 |

With both measures of effectiveness the Lockheed C-130H/Q is close to twice as effective as the next aircraft. The other two aircraft are not practical aircraft for fighting fires in Colorado.

# 2 Introduction

The State of Colorado is analyzing the cost effectiveness of the commercially available makes and models of Type 1 and Type 2 aircraft available to fight wildland fires in the state.

At present, there are two Type 1 makes and models available from commercial operators. These are:

| *Make and Model* | *Retardant Tank* |
|---|---|
| • Lockheed C-130Q | 3,500 Gallon |
| • British Aerospace BAe-146 | 3,000 Gallon |

Both these aircraft have certificated tank installations and have had their operational service life and the associated required inspections analyzed in accordance with the requirements of NTSB A04-029. Both aircraft have been in service with the US Forest Service on fire fighting contracts during 2013.

Two additional aircraft have been identified as potential aircraft for this mission:

| *Make and Model* | *Current Owner* | *Status* |
|---|---|---|
| • Alenia C-27J | US Air Force | Storage at Davis Monthan AFB |
| • Lockheed S-3B | US Navy | Storage at Davis Monthan AFB |

These aircraft are potentially viable Type 2 aircraft. However, neither of these aircraft has a certificated retardant tank installation nor have they had their operational service life and required inspections analyzed in accordance with the NTSB requirements.

It should be noted that the C-27J may not be available for this mission because of the 21 available aircraft, 7 are being transferred to the US Special Operations Command. And it has also been proposed to transfer the remaining 14 to the US Coast Guard who in turn would transfer 7 Lockheed C-130H aircraft to the US Forest Service under legislation recently introduced in Congress (the following link provides details: http://fireaviation.com/2013/11/22/legislation-introduced-to-transfer-7-c-130hs-to-us-forest-service/)

The following pages describe the aircraft, their actual or estimated retardant tank capacity and analyze the capabilities of all four aircraft in three primary areas:

- Mission payload capability from USFS air tanker bases in Colorado
- Sustainability and after sales product support
- Cost effectiveness as measured by cost per gallon delivered

# 3 Aircraft Analyzed

Four aircraft were analyzed for this study:

- Alenia C-27J
- British Aerospace BAe-146
- Lockheed C-130H/Q
- Lockheed S-3B

The following sections describe the general characteristics and summary performance for each aircraft. In addition, the retardant tank capacity of each aircraft is analyzed.

## *3.1 Alenia C-27J*

The **Alenia C-27J Spartan** is a medium-sized twin-engine turboprop military transport aircraft. The C-27J is an advanced derivative of Alenia Aeronautica's G.222 with the engines, propellers and certain systems of the Lockheed Martin C-130J Super Hercules. The C-27J has been ordered by the military air units of Australia, Italy, Greece, Bulgaria, Lithuania, Mexico, Morocco and Romania. The US Air Force operated 10 G-222 (C-27A Spartan in U.S. service) between 1990 and 1999. To date approximately 40 - 50 C-27J aircraft have been delivered. About 70 to 90 G-222, the C-27J's predecessor, are currently in service.

In 2007 this aircraft was the winner of a US Armed Forces Joint Cargo Aircraft (JCA) competition for about 100 aircraft. As a result of a variety of political and budgetary factors, the US Air Force ended up with the sole operational responsibility for the aircraft. Subsequently they reduced the order to 21 aircraft and then declared them surplus to their needs. The aircraft already delivered (16) are all in storage at the Davis Monthan AFB "bone yard". The remaining aircraft of the order for 21 aircraft will go directly into storage on delivery.

The Department of Defense is actively looking for interested users of these aircraft. As a result, 7 aircraft are being transferred to the US Special Operations Command. And currently there is proposed legislation in Congress to transfer the remaining 14 to the US Coast Guard. (The Coast Guard in turn would transfer 7 Lockheed C-130H aircraft to the US Forest Service). In other words, the C-27J aircraft may not be available for the fire fighting mission.

Some general characteristics and performance data for this aircraft are:

*General characteristics:*

Powerplant: 2 × Rolls-Royce AE2100-D2A turboprop @ 4,640 hp each
Crew: Minimum two: pilot, co-pilot
Length: 74 ft 6 in
Wingspan: 94 ft 2 in
Height: 31 ft 8 in

*Weights*

Empty operating weight: 46,200 lb (DOD configuration)
Empty operating weight: 42,900 lb (air tanker configuration)
Maximum Zero Fuel Weight: 58,422 lb
Maximum payload: 15,522 lb
Fuel capacity: 20,925 lb
Max takeoff weight: 67,241 lb
Max Landing weight: 60,626 lb

*Performance*

Maximum speed: 374 mph; 325 kts
Cruising speed: 362 mph; 315 kts
Minimum control speed: 121 mph; 105 kts
Ferry range: 3,680 mi; 3,200 nmi
Service ceiling: 30,000 ft
Fuel Consumption: 418 Gallon/Hr

### 3.1.1 Retardant Tank Capacity

Work on design and certification of a tank for the C-27J has not started. However, there is a certificated 1,800 gallon tank design for the previous model of this aircraft (the G-222).

The C-27J has a relatively low Maximum Zero Fuel Weight of 58,422 Lbs. This means that the total of the empty weight of the aircraft, the flight crew plus the weight of the retardant and the tank cannot exceed 58,422 Lbs. This Maximum Zero Fuel Weight is a function of the wing bending moment with light fuel loads and is a certificated limit because of the potential for structural failure when this limit is exceeded. The US Air Force, although not bound by civilian certification limits, applied this Maximum Zero Fuel Weight limit for its operations as well.

The C-27J as delivered to the US Air Force has an empty operating weight (including crew and miscellaneous equipment) of 46,200 Lbs. This can be reduced by removing the following:

| | |
|---|---|
| - Cockpit protective armor | 1,100 Lbs |
| - Cargo loading system | 1,200 |
| - Miscellaneous equipment | 1,000 |
| Total | 3,300 Lbs |

Removing this equipment lowers the empty operating weight (EOW) to 42,900 Lbs.

Subtracting this from the allowed Maximum Zero Fuel Weight yields the following available payload:

| | |
|---|---|
| - Maximum Zero Fuel Weight | 58,422 Lbs |
| - Empty Operating Weight | 42,900 |
| Available Payload (without tank) | 15,522 Lbs |

Assuming a weight of 9.0 Lbs/Gallon for retardant and adding 10% for the weight of the tank and the dispensing equipment (1,413 lb) yields an available retardant payload of 14,109 lb or, at 9.0 lbs/gallon, a tank capacity of 1,568 Gallon.

To increase tank carrying capacity beyond that volume requires relief from the Maximum Zero Fuel Weight Limitation. However, this required extensive engineering analysis and usually requires a reduction in maximum "g" capability or a reduction in maximum speed. A preliminary analysis by Convergent Performance LLC states that a constant flow type tank system with a capacity of 1,850 gallons can probably be developed for this aircraft while causing only minimal changes in the limitations.

Until the detailed structural analysis is done and approved by the manufacturer and EASA (the certificating authority) this aircraft cannot carry more than 1,568 gallons of retardant.

- C-27J Retardant Tank Capacity – Current: 1,568 Gallon
- C-27J Retardant Tank Capacity – Potential: 1,850 Gallon

When fully loaded with 1,568 gallons of retardant and fuel for 2.5 hours, the aircraft exceeds it maximum landing weight. This means that if it needs to land prior to releasing the retardant load it may need to release part or all of the retardant if it has not consumed enough fuel. Releasing retardant in this way is undesirable from an environmental point of view and expensive (retardant cost $4.00 per gallon).

This is illustrated in the following calculation:

| | |
|---|---|
| Operating empty weight | 44,315 lb |
| Retardant (1,568 Gallon) | 14,109 |
| Fuel (2.5 Hrs) | 7,000 |
| Total weight | 65,424 lb |
| | |
| Maximum landing weight permitted | 60,626 lb |
| | |
| Excess weight that must be unloaded | 4,798 lb |

## *3.2 British Aerospace BAe-146*

The **British Aerospace 146** (also **BAe 146**) is a regional airliner that was manufactured in the United Kingdom by British Aerospace, later part of BAE Systems. Production ran from 1983 until 2002. An improved version known as the **Avro RJ** began in 1992. A total of 387 aircraft produced during this aircraft’s production span.

The BAe 146/Avro RJ is a high-wing cantilever monoplane with a T-tail. It has four turbofan engines mounted on pylons underneath the wings, and has a retractable tricycle landing gear. In its primary role it serves as a regional jet, short-haul airliner or regional cargo airliner. The BAe 146/Avro RJ is in wide use among European airlines, but has seen only limited use in the US. At present there are about 150 of these aircraft left in service worldwide with less than 10 in service in the US.

One BAe 146 has been converted to a Type 1 Air Tanker and is on contract with the US Forest Service. The tank capacity is 3,000 gallons and the aircraft meets the requirements of NTSB A04-029. A second aircraft is reported to be in conversion.

*General characteristics*
Crew: 2 pilots
Length: 93 ft 10 in
Wingspan: 86 ft 0 in
Height: 28 ft 2 in
Powerplant: 4 × Honeywell ALF 502R-5 turbofans, 6,970 lbs thrust each

*Weights*
Empty weight: 50,400 lb (with retardant tank)
Max Zero Fuel weight: 75,000 lb (standard), 77,500 lb (modified for fire fighting)
Max. Payload: 27,100 lb (3,000 gallon of retardant)
Max fuel capacity: 20,320 lb
Max. takeoff weight: 93,000 lb
Max. Landing weight: 81,000 lb

*Performance*
Cruise speed: 498 mph (432 knots) at 29,000 ft (high speed cruise)
Range: 1,808 mi (1,570 nmi)(Standard fuel)
Minimum control speed: 95 Kts
Service ceiling: 30,000 ft
Fuel Consumption: 743 Gallon/Hr

### 3.2.1 Retardant Tank Capacity

A 3,000 gallon retardant tank has been designed and certificated for the BAe 146-200. One aircraft is on contract with the Forest Service. To allow carriage of the full 3,000 gallons an increase in the Maximum Zero Fuel Weight was required. The engineering for this increase was completed and the increase has been certificated.

- BAe 146-200 Retardant Tank Capacity: 3,000 Gallon

When fully loaded with 3,000 gallons of retardant and fuel for 2.5 hours, the aircraft exceeds it maximum landing weight. This means that if it needs to land prior to releasing the retardant load it may need to release part or all of the retardant if it has not consumed enough fuel. Releasing retardant in this way is undesirable from an environmental point of view and expensive (retardant cost $4.00 per gallon).

This is illustrated in the following calculation:

| | |
|---|---|
| Operating empty weight | 50,400 lb |
| Retardant (3,000 Gallon) | 27,000 |
| Fuel (2.5 Hrs) | 12,630 |
| Total weight | 90,030 lb |
| | |
| Maximum landing weight permitted | 81,000 lb |
| | |
| Excess weight that must be unloaded | 9,030 lb |

## *3.3 Lockheed C-130H/Q*

The **C-130 Hercules** is a four-engine turboprop military transport aircraft designed and built originally by Lockheed, now Lockheed Martin. Capable of using unprepared runways for takeoffs and landings, the C-130 was originally designed as a troop, medical evacuation, and cargo transport aircraft. The aircraft has been used for a variety of other roles, including aerial firefighting. It is in use with military forces worldwide. Over 40 models and variants of the Hercules serve with more than 60 nations. The C-130J is the current production model. The C-130H was produced between 1964 and 1996. The C-130Q is a variant of the C-130H that was equipped for surveillance and reconnaissance.

The C-130 entered service with the U.S. Air Force in the 1950s and since that time over 2,500 have been manufactured. A total of about 2,250 remain in service worldwide. Over 500 are in service in the US.

One C-130Q has been converted to a Type 1 Air Tanker and is on a “Next Gen” contract with the US Forest Service. The tank capacity is 3,500 gallons and the aircraft meets the requirements of NTSB A04-029.

Some general characteristics and performance data for this aircraft are:

*General characteristics*
Crew: 3 (2 pilots and 1 flight engineer)
Powerplant: 4 × Rolls Royce T56-A-15 turboprops, 4,590 shp each
Length: 97 ft 9 in
Wingspan: 132 ft 7 in
Height: 38 ft 3 in

*Weights*
Empty weight: 75,800 lb (with tanks installed)
Max Zero Fuel weight: 119,142 lb
Max. Payload: 43,342 lb
Max fuel capacity: 45,240 lb
Max. takeoff weight: 155,000 lb
Max. Landing weight: 155,000 lb

*Performance*
Maximum speed: 320 knots (366 mph) at 20,000 ft
Cruise speed: 292 kts (336 mph)
Range: 2,050 nmi (2,360 mi)
Service ceiling: 33,000 ft
Fuel consumption: 944 gallons/hour

### 3.3.1 Retardant Tank Capacity

A 3,500 gallon retardant tank has been designed and certificated for the C-130H/Q. One aircraft is on contract with the Forest Service.

- C-130H/Q Retardant Tank Capacity: 3,500 Gallon

When fully loaded with 3,500 gallons of retardant and fuel for 2.5 hours, the aircraft weighs less than its maximum landing weight. This means that if it needs to land prior to releasing the retardant load it does not need to release any retardant. This is a significant saving from both an environmental point of view and expense (retardant costs $4.00 per gallon). This is illustrated in the following calculation:

| | |
|---|---|
| Operating empty weight | 75,800 lb |
| Retardant (3,500 Gallon) | 31,500 |
| Fuel (2.5 Hrs) | 16,030 |
| Total weight | 123,330 lb |
| Maximum landing weight permitted | 155,000 lb |
| Excess weight that must be unloaded | 0 lb |

## 3.4 Lockheed S-3B

The **Lockheed S-3 Viking** is a four-seat twin-engine turbofan aircraft that was used by the U.S. Navy to identify and track enemy submarines. 186 S-3A were built between 1974 and 1978. Starting in 1987, the majority of the S-3As were upgraded to the **S-3B** variant. In the late 1990s, the S-3B's mission focus shifted to surface warfare and aerial refueling. A carrier-based, subsonic, all-weather, multi-mission aircraft with long range, it carried automated weapon systems, and was capable of extended missions with in-flight refueling.

The S-3B was retired from front-line fleet service aboard aircraft carriers by the US Navy in January 2009. All but a few aircraft are in storage at Davis Monthan AFB in Tucson, AZ. Three aircraft continue to be flown by the Air Test and Evaluation Squadron 30 (VX-30) at Naval Base Ventura County / NAS Point Magu, California and a single example is operated by the National Aeronautics and Space Administration (NASA) at the NASA Glenn Research Center.

*General characteristics*

Powerplant: 2 × General Electric TF34-GE-2 turbofans, 9,275 lb each
Crew: 4 (2 for civilian operations)
Length: 53 ft 4 in
Wingspan: 68 ft 8 in
Height: 22 ft 9 in

*Weights*
Empty weight with all combat/military equipment removed (est): 26,000 lb
Max carrier landing weight/Loaded weight: 38,192 lb*
Max Zero Fuel weight (est): 39,500 lb
Max. takeoff weight: 52,539 lb
Internal fuel capacity: 1,933 US gal

External fuel capacity: 2x 300 US gal tanks
**It is assumed this is similar to the civilian Max landing Weight.*

*Performance*
Maximum speed: Mach 0.79, 450 kn (514 mph) at 20,000 ft
Cruise speed: 350 kn (405 mph)
Stall speed: 97 kn (112 mph, 180 km/h)
Range: 2,765 nm (3,182 mi)
Service ceiling: 40,900 ft (12,465 m)
Fuel consumption: 400 gallon/hour

### 3.4.1 Retardant Tank Capacity

Work on design and certification of a tank for the S-3B has not started. The S-3B does not have a large open box-like cabin where a tank can be easily installed. Instead it has a bomb bay with a substantial keel beam running trough it. This keel beam is an integral part of the structure that allows the aircraft to be launched by catapult from a carrier and allows it to land on a carrier deck by using a tail hook. This means the tank and pumping/releasing gear will need to be designed around this keel beam. Two approaches were used to arrive at an estimate for the retardant tank capacity. One is based on a weight analysis. The other is based on an analysis of an aerial tanker version Lockheed proposed to the Navy.

- Weight Analysis Approach

The S-3B as stored at Davis Monthan AFB have an empty operating weight (including crew, all surveillance and communications equipment, aerial refueling system and miscellaneous equipment) of between 31,000 and 31,500 Lbs (for an average weight of 31,250 Lbs). Based on our discussions with the research team at NASA Glenn Research Center this can be reduced significantly by removing the following:

- Sonobuoy and bomb bay equipment
- US Navy surveillance and communications equipment
- Aerial refueling system
- Miscellaneous equipment

Total 4,250 Lbs

Removing this equipment lowers the empty operating weight (EOW) to 27,000 Lbs. NASA estimates the aircraft can be further lightened to about 26,000 lbs before installing fire fighting equipment weighing about 1,500 pounds. This would bring the operating weight with the tank installed to about 27,500 pounds.

The S-3B does not have a stated Maximum Zero Fuel Weight. There are two possible reasons for this. One is that the Maximum Zero Fuel Weight is the same as the

Maximum Take Off Gross Weight (52,539 Lbs). The other is that with a full complement of torpedoes, bombs and sonobuoy the stated mission empty weight is 38,192 Lbs. If this is well below the Maximum Zero Fuel Weight for the aircraft then there is no need to be concerned about the ZFW. Based on discussions with an experienced structural engineer familiar with carrier based aircraft it is reasonable to assume the aircraft has a ZFW of 39,000 to 40,000 Lbs.

Subtracting the empty weight from the maximum take off gross weight yields the following available useful load and payload:

| | |
|---|---|
| - Max TO Gross Weight | 52,539 Lbs |
| - Empty Operating Weight with tank | 27,500 |
| Useful load | 25,039 Lbs |
| - 2.5 Hrs of fuel @ 400 GPH | 6,700 |
| Available payload | 18,339 Lbs |

Assuming a weight of 9.0 Lbs/Gallon for retardant yields a tank capacity of 2,038 Gallon.

It should be noted that a study done by Argon ST, a subsidiary of Boeing, for the Forest Service states the S-3B has a “spare weight capacity” of 18,500 Lbs which equates to a tank capacity of about 1,850 gallons “before airframe modifications” and is capable of carrying 2,000 Gallons (presumably after these unspecified airframe modifications).

Alternatively, using the assumed Maximum Zero Fuel Weight of 39,000 to 40,000 Lbs (average is 39,500 Lbs) yields the following

| | |
|---|---|
| - Max Zero Fuel Weight | 39,500 Lbs |
| - Empty Operating Weight with Tank | 27,500 |
| Available payload | 12,000 Lbs |

Assuming a weight of 9.0 Lbs/Gallon for retardant and adding 10% for the weight of the tank and the dispensing equipment yields a tank capacity of 1,333 Gallon.

- KS-3B Aerial Refueling Version Approach

Lockheed at one point designed and proposed to the Navy an aerial tanker version of the S-3B – the KS-3B. According to Navy personnel we spoke to the KS-3B would have had a total fuel capacity of 4,200 gallons. The standard wing fuel tank plus the two drop tanks hold a total of 2,460 gallon. This means that the additional tank installed in the bomb bay was able to hold about 1,740 gallon. At a weight per gallon of JP-4 of 6.8 Lbs/Gallon this equates to 11,832 Lbs.

If the tank capacity were limited by the space available in the bomb bay, then the bomb bay fuel tank would be able to hold 1,740 gallons of retardant.

If on the other hand the tank capacity were limited by a weight restriction (such as the Maximum Zero Fuel Weight), then the retardant load would be limited to 11,832 Lbs or (at 9 Lbs/Gallon) 1,315 Gallon.

Any airframe modifications (such as mentioned by the Argon ST study) or any increases in Maximum Zero Fuel Weight limits require extensive engineering analysis and certification.
Without a detailed engineering and structural analyses it is impossible to determine the structural and weight limits on this aircraft.

For the purposes of this study we have used the average of the different approaches to tank capacity discussed above:

| | |
|---|---|
| - Weight analysis – TO Gross Weight | 2,038 |
| - Weight analysis – Maximum Zero Fuel Weight | 1,333 |
| - KS-3B tank capacity | 1,740 |
| - KS-3B equivalent fuel weight | 1,315 |
| Average | 1,607 |

- S-3B Retardant Tank Capacity – Estimated: 1,607 Gallon

When fully loaded with 1,607 gallons of retardant and fuel for 2.5 hours, the aircraft exceeds its assumed maximum landing weight. This means that if it needs to land prior to releasing the retardant load it may need to release part or all of the retardant if it has not consumed enough fuel. Releasing retardant in this way is undesirable from an environmental point of view and expensive (retardant cost $4.00 per gallon).

This is illustrated in the following calculation:

| | |
|---|---|
| Operating empty weight with Tank | 27,500 lb |
| Retardant (1,607 Gallon) | 14,463 |
| Fuel (2.5 Hrs) | 6,700 |
| Total weight | 48,663 lb |
| | |
| Assumed maximum landing weight permitted | 39,182 lb |
| | |
| Excess weight that must be unloaded | 9,481 lb |

## *3.5 Retardant Tank Volume Summary*

The following table summarizes the analysis of the retardant tank volume for the four aircraft:

**Retardant Tank Volume Summary**

| | | Tank Volume | Comments |
|---|---|---|---|
| | | | |
| Alenia | C-27J | 1,850 | Estimate |
| | | | |
| British Aerospace | BAe 146-200 | 3,000 | Certificated |
| | | | |
| Lockheed | C-130H/Q | 3,500 | Certificated |
| | | | |
| Lockheed | S-3B | 1,607 | Preliminary Estimate |

# 4 Mission Payload Analysis from USFS Airtanker Bases in Colorado

The payload analysis is focused on Colorado and the four US Forest Service Air Attack Bases in that state:

| | *City* | *Airport* | *Elevation* | *Runway Length* |
|---|---|---|---|---|
| - | Denver | BJC | 5,673 Ft | 9,000 Ft |
| - | Durango | DRO | 6,685 | 9,201 |
| - | Grand Junction | GJT | 4,858 | 10,501 |
| - | Pueblo | PUB | 4,726 | 10,496 |

The analyses were all accomplished at a temperature of:

*Temperature:*
- ISA + 30 degree C.

Each aircraft in the analysis is assumed to have 2.5 hours of fuel on board for both mission fuel and reserve fuel. This equates to the following fuel load for each aircraft:

| | *Aircraft* | *Fuel Consumption/Hr* | *2.5 Hour Fuel Load* |
|---|---|---|---|
| - | Alenia C-27J | 418 GPH | 7,000 Lbs |
| - | BAe 146-200 | 743 | 12,631 |
| - | Lockheed C-130H/Q | 944 | 16,048 |
| - | Lockheed Sk3B | 400 | 6,700 |

The retardant payload is determined by the most restrictive of the following four factors:

*Payload Limit*
- Retardant tank size (see sections 3.1.1, 3.2.1, 3.3.1 and 3.4.1 above)
- Structural payload limit (as determined by the maximum zero fuel weight limit)
- Takeoff runway length required as determined through a Balanced Field Length analysis
- Engine out climb requirements as determined by a Second Segment Climb analysis

Use of the Balanced Field Length (BFL) concept to calculate the runway length required for a particular airport means that the aircraft can lose all power on one engine at any time during the take off sequence and either come to a full stop within the available runway length or it can continue its take off, become airborne and clear a 35 foot obstacle at the end of the runway.

The Second Segment Climb requirement applies the same concept to the most critical portion of the climb profile after takeoff. To meet this criterion an aircraft, with takeoff flaps extended but with the landing gear retracted, must be able to climb with one engine inoperative at a minimum gradient of 2.4% until it reaches an altitude of 400 feet above the airport.

Both of these are very important safety features because they allow the aircraft that meet these requirements to lose all power on one engine at any time during the take off and climb sequence and either stop on the remaining runway or continue its climb out and return safely to the airport.

These criteria apply to all commercial jet aircraft as well as turboprop aircraft that have a maximum take off gross weight over 12,500 Lbs. For that reason they have been applied to all four aircraft included in this performance analysis.

It can be argued that since an Air Tanker can release its retardant load in a very short period of time, it could take off at a weight that exceeds the single engine climb requirements and then release its retardant load to regain altitude during climb when an engine malfunctions. However, this cannot be done over populated areas and also should not be done if the visibility restricted at the departing airport to avoid potentially serious injure to persons or damage property.

It should be noted that compared to a 2-engine aircraft, a 4-engine aircraft is at a significant advantage in meeting these requirements. The reason is that when a 2-engine aircraft loses power on one engine it loses 50% of its available power, while a 4-engine aircraft loses only 25%.

All performance calculations for this analysis were done under typical summer temperature conditions (ISA + 30 degrees C). This temperature equates to 95 degrees F at 5,000 foot elevation. All performance data was obtained from the appropriate approved Flight and Performance manuals. The results of the analysis are as follows:

## *4.1 Alenia C-27J*

The size of the planned tank is 1,850 gallons.

The first step involves a detailed weight build up, as shown in the following table to determine the structural payload limit and the required take off gross weight to carry the maximum structural payload and the required 2.5 hours of fuel. This results in a structural payload limit of 14,109 lbs of retardant which equates to a tank volume of 1,568 gallons. The corresponding take off gross weight is 65,122 lbs, as shown in the following table.

| **Weight Buildup** | Pounds |
|---|---|
| Operating Empty Wt, USAF | 46,200 |
| Mission Equipment Removed | (3,300) |
| Equipment Added - Tank, etc. | 1,413 |
| Operating Empty Wt, Equipped | 44,313 |
| Max ZFW | 58,422 |
| Max Structural Payload | 14,109 |
| Max Structural Payload (USG) | 1,568 |

| | |
|---|---|
| Weight of Aircraft with Payload | 58,422 |
| Mission Fuel 2.5 Hours | 7,000 |
| Actual TOW (Max TOW = 67,240 lbs) | 65,422 |

Next the Balanced Field Length (BFL) and Second Segment Climb calculations were performed using the appropriate charts from the Flight and Performance manuals. The results for the ISA + 30 deg C. analysis are shown in the following table.

**Max Takeoff Weight limited by takeoff /climb performance at ISA + 30C**

| | **Field Elevation (Ft)** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Runway** | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
| 4500 Ft | 59,500 | 59,000 | 55,000 | 56,000 | 54,000 | 53,000 | 51,500 |
| 5000 | 59,500 | 59,000 | 58,000 | 57,000 | 55,500 | 54,000 | 53,000 |
| 5500 | 59,500 | 59,000 | 58,000 | 57,000 | 55,500 | 54,000 | 53,000 |
| 6000 | 59,500 | 59,000 | 58,000 | 57,000 | 55,500 | 54,000 | 53,000 |
| 6500 | 59,500 | 59,000 | 58,000 | 57,000 | 55,500 | 54,000 | 53,000 |

**Payload Limit USG**

| | **Field Elevation (Ft)** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Runway** | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
| 4500 Ft | 700 | 644 | 200 | 311 | 89 | (22) | (189) |
| 5000 | 700 | 644 | 533 | 422 | 256 | 89 | (22) |
| 5500 | 700 | 644 | 533 | 422 | 256 | 89 | (22) |
| 6000 | 700 | 644 | 533 | 422 | 256 | 89 | (22) |
| 6500 | 700 | 644 | 533 | 422 | 256 | 89 | (22) |

*Payload limited by:*

| |
|---|
| Balanced Field Length |
| Second Segment Climb |

Based on this analysis, the amount of retardant that can be carried from each of the four airports by the C-27J at ISA + 30 deg C is:

| *City* | *Airport* | *Retardant Volume* |
|---|---|---|
| - Denver | BJC | 142 Gallon |
| - Durango | DRO | 13 |
| - Grand Junction | GJT | 279 |
| - Pueblo | PUB | 301 |

## *4.2 British Aerospace BAe 146-200*

The size of the installed tank is 3,000 gallons.

The detailed analysis for this aircraft was accomplished in support of a previous study entitled "An Analysis of Payload Performance of the BAe-146 and RJ85 Aircraft in the USFS Airtanker Mission", dated Aug 2, 2012.

Based on this analysis, the amount of retardant that can be carried from each of the four airports by the BAe 146-200 at ISA + 30 deg C is:

| | *City* | *Airport* | *Retardant Volume* |
|---|---|---|---|
| - | Denver | BJC | 1,804 Gallon |
| - | Durango | DRO | 1,568 |
| - | Grand Junction | GJT | 1,993 |
| - | Pueblo | PUB | 2,009 |

## *4.3 Lockheed C-130H/Q*

The size of the installed tank is 3,500 gallons.

The detailed analysis for this aircraft was accomplished in support of a previous study entitled "An Analysis of Payload Performance of the BAe-146 and RJ85 Aircraft in the USFS Airtanker Mission", dated Aug 2, 2012.

Based on this analysis, the amount of retardant that can be carried from each of the four airports by the BAe 146-200 at ISA + 30 deg C is:

| | *City* | *Airport* | *Retardant Volume* |
|---|---|---|---|
| - | Denver | BJC | 3,500 Gallon |
| - | Durango | DRO | 3,500 |
| - | Grand Junction | GJT | 3,500 |
| - | Pueblo | PUB | 3,500 |

## *4.4 Lockheed S-3B*

The estimated size of the retardant tank that can be installed in this aircraft is 1,607 gallons.

The first step involves a detailed weight build up, as shown in the following table to determine the structural payload limit and the required take off gross weight to carry the maximum structural payload and the required 2.5 hours of fuel. This results in a structural payload limit of 12,000 lbs. of retardant which equates to a tank volume of 1,333 gallons. The corresponding take off gross weight is 46,200 lbs, as shown in the following table.

| **Weight Buildup** | Pounds |
|---|---|
| Operating Empty Wt (with tank) | 27,500 |
| Max ZFW (Est) | 39,500 |
| Max Structural Payload | 12,000 |
| Max Structural Payload (USG) | 1,333 |
| | |
| Weight of Aircraft with Payload | 39,500 |
| Mission Fuel 2.5 Hours | 6,700 |
| Actual TOW (Max TOW = 67,240 lbs) | 46,200 |

Next the Balanced Field Length (BFL) and Second Segment Climb calculations were performed using the appropriate charts from the Flight and Performance manuals. The results for the ISA + 30 deg C. analysis are shown in the following table.

**Max Takeoff Weight limited by takeoff /climb performance at ISA + 30C**

| | **Field Elevation** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Runway** | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
| 4500 | 39,000 | 38,000 | 37,000 | 36,000 | 35,000 | 34,000 | 33,000 |
| 5000 | 40,875 | 39,750 | 38,625 | 37,500 | 36,375 | 35,250 | 34,000 |
| 5500 | 40,875 | 39,750 | 38,625 | 37,500 | 36,375 | 35,250 | 34,125 |
| 6000 | 40,875 | 39,750 | 38,625 | 37,500 | 36,375 | 35,250 | 34,125 |
| 6500 | 40,875 | 39,750 | 38,625 | 37,500 | 36,375 | 35,250 | 34,125 |

**Payload Limit USG**

| | **Field Elevation** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Runway** | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
| 4500 | 533 | 422 | 311 | 200 | 89 | (22) | (133) |
| 5000 | 742 | 617 | 492 | 367 | 242 | 117 | (22) |
| 5500 | 742 | 617 | 492 | 367 | 242 | 117 | (8) |
| 6000 | 742 | 617 | 492 | 367 | 242 | 117 | (8) |
| 6500 | 742 | 617 | 492 | 367 | 242 | 117 | (8) |

*Payload limited by:*

| |
|---|
| Balanced Field Length |
| Second Segment Climb |

Based on this analysis, the amount of retardant that can be carried from each of the four airports by the S-3B at ISA + 30 deg C is:

| | *City* | *Airport* | *Retardant Volume* |
|---|---|---|---|
| - | Denver | BJC | 157 Gallon |
| - | Durango | DRO | 31 |
| - | Grand Junction | GJT | 259 |
| - | Pueblo | PUB | 276 |

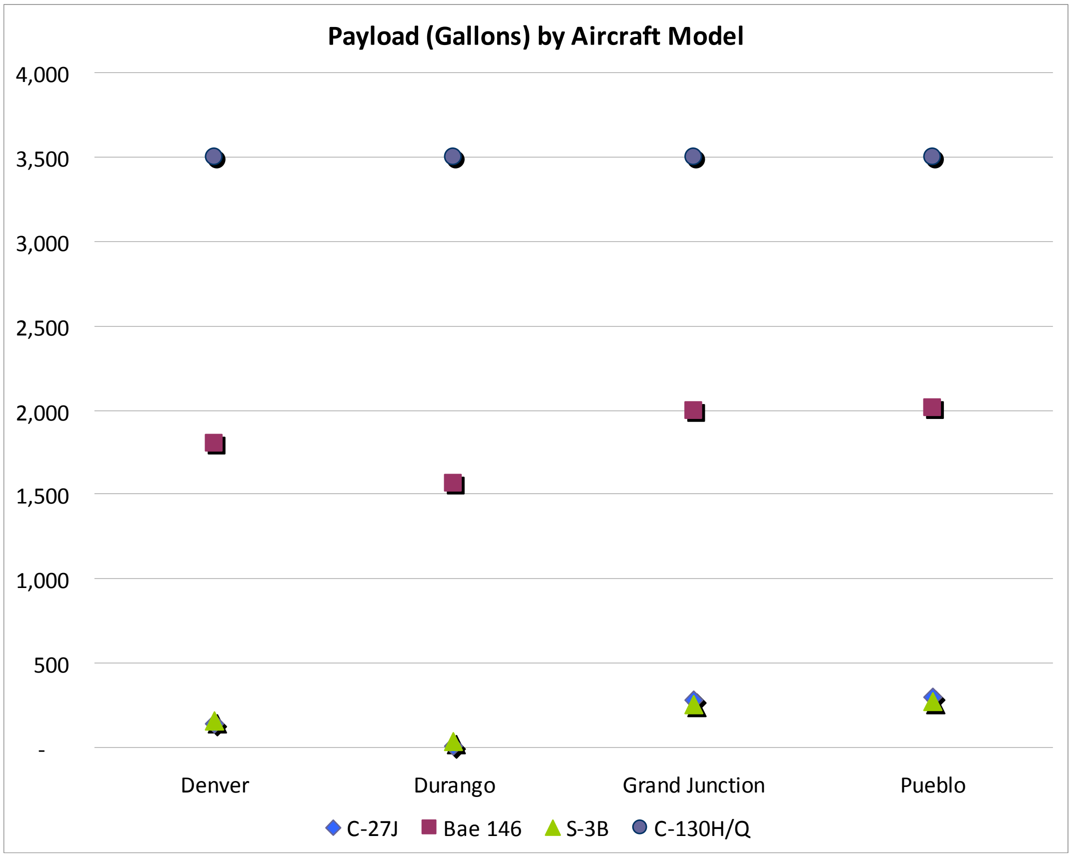
## *4.5 Retardant Payload Summary*

The retardant that each aircraft can carry from each of the four Colorado Air Tanker bases with typical summer temperatures is summarized and averaged in the following table:

**Retardant Delivery Capability (Gallons)**

| | | C-27J | BAe 146 | S-3B | C-130H/Q |
|---|---|---|---|---|---|
| Denver | BJC | 142 | 1,804 | 157 | 3,500 |
| Durango | DRO | 13 | 1,568 | 31 | 3,500 |
| Grand Junction | GJT | 279 | 1,993 | 259 | 3,500 |
| Pueblo | PUB | 301 | 2,009 | 276 | 3,500 |
| | | | | | |
| Average | | 184 | 1,844 | 181 | 3,500 |

And in graphical format:



# 5 Sustainability/After Sales Product Support

Four major areas were analyzed for this part of the analysis:
- Production status
- In-service fleet size
- Compliance with NTSB A04-029 recommendations
- Certification (STC) of retardant tank system

The reason for analyzing each of these is discussed in the following sections.

## 5.1 Production status

The production status of an aircraft is a direct measure of the technical support available from the manufacturer to resolve maintenance and reliability problems as well as the long-term availability of spare parts unique to the aircraft.
- If the aircraft or a related model is in production, experience shows the level of support from the manufacturer (engine, airframe and avionics) is substantially better than if the aircraft is out of production.
- Similarly, if the manufacturer is still in the business of building similar aircraft the support is likely to be much better than if the manufacturer is no longer in that business.

To allow comparison of the production status of each aircraft, the following scoring scale will be used:

| *Production Status* | *Level of Involvement* | *Score* |
|---|---|---|
| In production | Builds Aircraft in Class | 1 |
| Related Model in production | Builds Aircraft in Class | 2 |
| Out of Production | Builds Aircraft in Class | 3 |
| Out of Production | Builds Other Aircraft | 4 |

A review of the production status of the four aircraft shows the following:

- Lockheed C-130H/Q Score = 2

The Lockheed C-130 has been in continuous production since the 1950s and has been sold worldwide to numerous armed forces. The current model is the C-130J. The C-130H/Q was in production from 1964 – 1996. Lockheed builds the C-130 in Marietta, GA and has a large, world-wide engineering, technical support and logistics support operation for these aircraft headquartered there.

- British Aerospace BAe 146 Score = 4

The BAe 146-100/200/300 and its successor, the RJ 75/85/100 were manufactured by British Aerospace between 1983 and 2002. The aircraft was aimed at the regional airline market. This aircraft, which was only moderately successful, was the last airline/transport aircraft built by the company. BAE Systems, the successor company, builds only fighter aircraft but has a division that provides support for the BAe 146 and the other commercial aircraft it formerly manufactured and that are still in service.

- Alenia C-27J Score = 1

The Alenia C-27J is an Italian aircraft in current production. It is an upgraded, re-engined version of the G-222 and both are in service with a number of foreign military services. Alenia has an active support program that is based in Italy. Originally, this aircraft was the winner of a Joint Cargo Aircraft competition for about 100 aircraft. As a result of a variety of political and budgetary factors, the US Air Force ended up with the sole operational responsibility for the aircraft. They then reduced the order to 21 aircraft and then declared them surplus to their needs. The aircraft already delivered are all in storage at the Davis Monthan AFB "bone yard". The remaining aircraft of the order for 21 aircraft will go directly into storage on delivery.

- Lockheed S-3B Score = 4

The Lockheed S-3B was a US Navy carrier-based anti-submarine warfare aircraft. A total of about 185 were produced between 1974 and 1978. The aircraft was in service with the US Navy until about 2008. The aircraft are currently in storage at Davis Monthan AFB. Lockheed does not build carrier based ASW aircraft anymore. It currently builds fighter and cargo aircraft.

## *5.2 In-service fleet size*

This measure examines the infrastructure available from the manufacturer and other vendors for spare parts, heavy maintenance and technical support of the aircraft. Generally speaking, the larger the in-service fleet and specifically the US based in-service fleet, the better the support infrastructure for US operators. This support level has a direct impact on availability and reliability of the aircraft. An additional factor governed by the in-service fleet size is the availability of qualified flight and maintenance personnel as well as the availability of formal, simulator based training programs. Typically, when more than 500 aircraft are in the active fleet, the support programs will be robust. By the same token, if the active fleet is less than 50, the support will be poor. To allow comparison of the US in-service fleet status of each aircraft, the following scoring scale will be used:

| *Fleet in North America* | *Score* |
|---|---|
| > 500 | 1 |
| 251 - 500 | 2 |
| 101 - 250 | 3 |
| 50 - 100 | 4 |
| < 50 | 5 |

A review of the in-service fleet status of the four aircraft shows the following:

- Lockheed C-130H/Q Score = 1

Over 2,500 C-130 aircraft have been produced and over 2,250 are in service worldwide. Of these over 500 are in service in North America, primarily with the US Armed Forces but also with a number of non-military and commercial operators. Lockheed and Rolls Royce (the manufacturer of the engines) have developed a very robust support structure and there are numerous other vendors that supply spares and/or repair and overhaul components.

Qualified flight and maintenance personnel are readily available in the civilian market as are simulator based training programs.

Based on these factors, this item is scored "1".

- British Aerospace BAe 146 Score = 5

British Aerospace originally built 390 of these aircraft. They proved to be expensive to maintain and at present less than 150 are still in service worldwide. The aircraft was never very popular with the airlines in North America and as a result less than 10 are still in service in N. America. While it is true that BAE Systems does a fair job of providing support for these aircraft, the support infrastructure in the US is rapidly shrinking.

Qualified flight and maintenance personnel are still available in the civilian market as are simulator based training programs.

Based on these factors, this item is scored "5".

- Alenia C-27J Score = 3

To date over 150 of this model and its predecessor have been built and the active fleet worldwide is about 125. There are at present no active C-27J aircraft in the US. If the aircraft in storage are transferred to new users, Alenia undoubtedly will provide some level of support. One unique feature of this aircraft is that it uses the engines, propellers, avionics and cockpit displays as well as some systems from the C-130J. This is the result of a cooperative program with Lockheed prior to the competition for the Joint

Cargo Aircraft. After the design was completed, Lockheed withdrew from the partnership. Nevertheless, Alenia chose to offer the C-27J with the C-130J engines, propellers, etc. The advantage of this is that there is a very robust supply chain to support those parts of the C-27J that are common with the C-130J.

Qualified flight and maintenance personnel are in very limited supply in the US civilian market. A simulator based training program is available at the manufacturer in Italy.

As a result this item is scored as a "3" – the average of "5" for the N. America C-27J in-service fleet and a "1" for the C-27J systems that are common with the C-130J.

- Lockheed S-3B Score = 4

Lockheed built a total of 186 of these aircraft for the US Navy. No other aircraft were built for any other customer. The last aircraft was retired from US Navy carrier duty in about 2008. At present there are perhaps 5 aircraft left in service with NASA (as an R&D aircraft) and the Navy (for a special project). As a result, the support infrastructure is rapidly disappearing. The only bright spot is that apparently there is a large store of spare parts that was retired and placed in storage at the same time as the aircraft were retired. The only problem with these parts is that the storage conditions and the quality of the documentation of these parts are not known. In addition, any parts with calendar based life limits will not be usable when their calendar life has expired. The other factor to consider is that the engine for these aircraft is a military version of a very successful commercial engine. As a result there should be reasonably good support for this engine.

Qualified flight and maintenance personnel should still be available in the civilian market. However, a simulator based training program is not available. Apparently, a US Navy owned simulator has also been placed in storage and is probably available to a future operator of these aircraft. However, the cost of operation and maintaining this simulator for a small fleet may be prohibitive.

Based on these factors, this item is scored as a "4" – the average of "5" for the N. America S-3B in-service fleet and a "3" for the spares supply presumably sized to support a fleet of 186 that are currently in storage.

## *5.3 Compliance with NTSB A04-029 recommendations*

In 2003, contractors flying fire fighting air tankers had two fatal accidents that were the result of structural failure. The NTSB investigation of these two accidents resulted in the publication by the NTSB of a set of recommendations regarding the determination of the safe structural life of aircraft used for fire fighting. The recommendations are contained in a document referred to as the NTSB A04-029 standards. The US Forest Service adopted these recommendations in their entirety and mandated that any aircraft used on USFS fire fighting contracts comply with these standards.

To comply with these standards, a very detailed analysis needs to be performed that determines the impact on the structural integrity of the “g” loading patterns caused by the very turbulent air over a large fire, the release of a very large quantity of water (up to 32,000 lbs) in a very short time span and the corrosiveness of the smoke present at a large fire. Based on this analysis, the areas affected are identified and the impact on the structural life is calculated. Then an appropriate inspection and repair program is established to assure that any problems are identified and repaired well before they cause potential structural failure. One of the interesting factors that was uncovered during the NTSB analysis of the 2003 accidents is that the structural and corrosive stresses on an aircraft used for fire fighting are unique. Thus, while some aircraft are much more capable than others to withstand the rigors of fire fighting, only a formal engineering analysis in accordance with NTSB A04-029 will establish the structural life and required inspection areas and programs for an aircraft used for fire fighting.

The engineering analysis and development of the structural life limit and inspection program requires about one year and costs between $500,000 and $700,000.

Compliance with this NTSB recommendation is mandatory for the USFS is to use an aircraft. This requires that any aircraft used by the USFS for fire fighting must either meet this standard or be in the process of meeting it.

Based on this, the following scoring scale will be used to compare the various aircraft.

| *NTSB Compliance* | *Score* |
|---|---|
| Complies | 1 |
| In work | 2 |
| Started | 3 |
| Not started | 4 |

A review of the status of the four aircraft with respect to NTSB A04-029 shows the following:

- Lockheed C-130H/Q Score = 1
- British Aerospace BAe 146 Score = 1

Both aircraft are fully compliant with the requirements.

- Alenia C-27J Score = 4
- Lockheed S-3B Score = 4

Neither of these two aircraft has started the analysis process required to comply with NTSB A04-029.

## *5.4 Certification (STC) of retardant tank system*

A retardant tank system can be certificated for almost any aircraft. However, it requires money and time – the estimated cost for design, fabrication, installation, testing and certification is $1.6 million and the time required is about 12 months. Therefore, if an aircraft already has this STC they are ready to start work soonest. If the operator is in the process of getting an STC or the STC for a tank installation is available for a related model the amount of time required before the aircraft is ready to start fighting fires is reduced. If no work has started on obtaining a certificated STC for the tank installation for a particular aircraft it will take longest to get the aircraft ready for fire fighting.

Based on this, the following scoring scale will be used to compare the various aircraft.

| *Tank Design/STC* | *Score* |
|---|---|
| Certificated | 1 |
| STC In Work | 2 |
| STC For Related Model | 3 |
| STC Work Not started | 4 |

A review of the retardant tank STC status of the four aircraft shows the following:

- Lockheed C-130H/Q Score = 1
- British Aerospace BAe 146 Score = 1

Both aircraft have fully certificated retardant tank installations. The tank of the C-130 is 3,500 gallons and the one on the BAe 146 is 3,000 gallons.

- Alenia C-27J Score = 3

Work on design and certification of a tank for the C-27J has not started. However, there is a certificated tank design for the previous model of this aircraft (the G-222). In addition, preliminary analysis has shown that a constant flow type tank system can be developed for this aircraft. Estimated maximum tank capacity is 1,850 gallon for this aircraft based on its Maximum Zero Fuel Weight limitations.

Based on the certificated pre-existing G-222 tank system, this item is assigned a score of "3" for this aircraft.

- Lockheed S-3B Score = 4

The Lockheed S-3B does not have a certificated tank system. It will also be difficult to adapt an existing system to this aircraft because the bomb bay, which is were the tank would need to be installed, has a massive structural keel running through the bottom of the bomb bay. This keel, which runs from nose to tail, is a primary structural element of this aircraft that was required to allow catapult carrier launches and tail hook arrested landings.

To design, install and certificate a tank design will be complicated and time consuming. As a result this item is scored a “4”.

## *5.5 Overall Sustainability Ranking*

The results of the sustainability analysis discussed in the previous sections are summarized in Table 4.1 below.

This shows that the Lockheed C-130H/Q has the best sustainability ranking, followed by the BAe 146 and the Alenia C-27J. The Lockheed S-3B ranks last.

**Sustainability Ranking** **Table 4.1**

| Aircraft | Alenia | Lockheed | British Aerospace | Lockheed |
|---|---|---|---|---|
| Model | C27J | S3B | BAe 146 | C130H/Q |
| | | | | |
| **Production Status** | | | | |
| Status | In production | Out of Production | Out of Production | Related Model in Prod |
| Manufacturer | Active in Class | Builds Aircraft | Builds Aircraft | Active in Class |
| | | | | |
| Score | 1 | 4 | 4 | 2 |
| | | | | |
| **In Service Fleet** | | | | |
| Total (All Models) | 150 + | 186 | 390 | 2500 + |
| In Service | | | | |
| - Worldwide | 125+ | < 10 | < 150 | 2250 + |
| - North America | 0 | < 10 | < 10 | 500 + |
| | | | | |
| Score | 3 | 4 | 5 | 1 |
| | | | | |
| **NTSB A04-029** | Not Started | Not Started | Complies | Complies |
| Score | 4 | 4 | 1 | 1 |
| | | | | |
| **Retardant Tank Status** | Adapt Exist. Design | New Design Req | STC Obtained | STC Obtained |
| | | | | |
| Score | 3 | 4 | 1 | 1 |
| | | | | |
| **Composite Score** | 11 | 16 | 11 | 5 |
| | | | | |
| **Ranking*** | 2 | 4 | 2 | 1 |

# 6 Fire Fighting Effectiveness of Aircraft Analyzed.

The fire fighting effectiveness of the four aircraft in this study was analyzed from two perspectives:

- The average number gallons of retardant per hour that can be delivered using a nominal flight profile in Colorado
- The number of gallons of retardant that can be dropped with 5 flights by one aircraft from each base.

This analysis is focused on Colorado and the four US Forest Service Air Attack Bases in that state:

| *City* | *Airport* | *Elevation* | *Runway Length* |
|---|---|---|---|
| Denver | BJC | 5,673 Ft | 9,000 Ft |
| Durango | DRO | 6,685 | 9,201 |
| Grand Junction | GJT | 4,858 | 10,501 |
| Pueblo | PUB | 4,726 | 10,496 |

Temperature used for the analysis is a typical summer temperature -- ISA + 30 degree F.

## *6.1 Retardant Delivery – Gallons per Hour*

The goal during an initial attack (IA) is to get the most retardant on the fire in the shortest possible time. The metric that best measures this goal is gallons of retardant delivered per hour. This takes into account not just the cruise speed of an aircraft but also the other time factors and the number of gallons that can be carried from the available Air Attack Base(s).

The first part of the analysis starts with the number of gallons of retardant that can be carried aloft by each aircraft from the four bases the analysis shown in section 3.0 shows the following for a typical ISA + 30 deg C day:

**Retardant Delivery Capability per Flight (Gallons)**

| | | **C-27J** | **BAe 146** | **S-3B** | **C-130H/Q** |
|---|---|---|---|---|---|
| Denver | BJC | 142 | 1,804 | 157 | 3,500 |
| Durango | DRO | 13 | 1,568 | 31 | 3,500 |
| Grand Junction | GJT | 279 | 1,993 | 259 | 3,500 |
| Pueblo | PUB | 301 | 2,009 | 276 | 3,500 |
| | | | | | |
| Average | | 184 | 1,844 | 181 | 3,500 |

Next a nominal delivery flight profile was established by calculating the average distance to get to any point in the mountainous part of the state from the nearest Air Attack Base. This distance is 100 Miles or 87 N. Miles.

The trip profile used is composed of the following elements:

| | | |
|---|---|---|
| Start/Taxi/TO | Min | 8 minutes plus 2 minutes per engine start |
| Flight to target | Min | Climb, cruise and descent. Max cruise alt. = 20,000 Ft |
| On station time | Min | 15 minutes wait time plus delivery run |
| Return to base | Min | Same as "Flight to target" |
| Land/taxi/shut down | Min | 5 minutes |
| Reload | Min | 10 minutes to position and hook up plus 1 minute/500 gallon |
| Total time | Min | |

This profile is based on operator experience.

Combining the average gallons carried, the average distance and the typical flight profile yields the following delivery rate in gallons per hour for each aircraft.

**Aircraft Retardant Delivery Capability**

| Model | | C 27J | BAe 146 | S-3B | C 130H/Q |
|---|---|---|---|---|---|
| | | | | | |
| Average Gallons Carried | Gallon | 184 | 1,844 | 181 | 3,500 |
| | | | | | |
| Engines | | 2 | 4 | 2 | 4 |
| Ave Speed @ 20,000 Ft | KTAS | 250 | 300 | 300 | 250 |
| Distance to target | NM | 87 | 87 | 87 | 87 |
| | | | | | |
| | | | | | |
| Start/Taxi/TO | Min | 12 | 16 | 12 | 16 |
| Flight to target | Min | 21 | 17 | 17 | 21 |
| On station time | Min | 15 | 15 | 15 | 15 |
| Return to base | Min | 21 | 17 | 17 | 21 |
| Land/taxi/shut down | Min | 5 | 5 | 5 | 5 |
| Reload | Min | 13 | 14 | 11 | 17 |
| Total time | Min | 86 | 84 | 78 | 95 |
| | | | | | |
| Gallons per Hour | GPH | 128 | 1,317 | 139 | 2,211 |

This analysis, which takes into account both gallons carried and time to target, shows that the C-130H/Q delivers the highest number of gallons per hour by a very substantial margin, followed by the BAe 146. Both deliver substantially more retardant than the C-27J and the S-3B. From a practical point of view the S-3B are C-27J are not suitable aircraft for the Colorado fire fighting mission because of the small amount of retardant they can deliver when all performance factors are considered.

The other issue that this metric highlights is that the significantly higher cruise speed of the BAe 146, a jet, results in a flight time (take off to arrival at the staging point for the attack) of only 4 minutes less than for the C-130H/Q, a turboprop.

The longest distance to any point in the state from the nearest Air Attack Base is about 145 St. Miles (from Grand Junction to the NW border of the state). Even for this distance the speed advantage of the jet (BAe 146) only reduces the flight time by 5 minutes (30 minutes as compared to 25 minutes).

In other words, the significantly higher cruise speed of a jet overall has a very small impact on the retardant delivery capability off the aircraft.

## *6.2 Retardant Delivery Comparison*

This part of the effectiveness analysis again starts the number of gallons that can be carried on each flight:

**Retardant Delivery Capability per Flight (Gallons)**

| | | C-27J | BAe 146 | S-3B | C-130H/Q |
|---|---|---|---|---|---|
| Denver | BJC | 142 | 1,804 | 157 | 3,500 |
| Durango | DRO | 13 | 1,568 | 31 | 3,500 |
| Grand Junction | GJT | 279 | 1,993 | 259 | 3,500 |
| Pueblo | PUB | 301 | 2,009 | 276 | 3,500 |
| | | | | | |
| Average | | 184 | 1,844 | 181 | 3,500 |

Based on this, the number of gallons of retardant that can be delivered with 5 flights by one aircraft from each base is shown in the following table.

**Retardant Delivered by One Aircraft with 5 Flights (Gallons – ISA + 30 deg C)**

| | | C-27J | BAe 146 | S-3B | C-130H/Q |
|---|---|---|---|---|---|
| Denver | BJC | 710 | 9,020 | 785 | 17,500 |
| Durango | DRO | 65 | 7,840 | 155 | 17,500 |
| Grand Junction | GJT | 1,395 | 9,965 | 1,295 | 17,500 |
| Pueblo | PUB | 1,505 | 10,045 | 1,380 | 17,500 |
| | | | | | |
| Average | | 919 | 9,218 | 904 | 17,500 |

The C-130H/Q delivers approximately twice as much retardant in five flights as does the next most capable aircraft. The C-130H/Q also delivers twenty times as much retardant in five flights as the C27J and the S-3B.

## *6.3 Overall Retardant Delivery Effectiveness*

Combining the results of these two measures of effectiveness and ranking them shows that the Lockheed C-130H/Q is substantially more effective that the other three aircraft in delivering retardant to the fire.

**Retardant Delivered Effectiveness Ranking (ISA + 30 deg C)**

| | **C-27J** | **Bae 146** | **S-3B** | **C-130H/Q** |
|---|---|---|---|---|
| Gallons/Hour | 3 | 2 | 3 | 1 |
| Gallons with 5 Flights | 3 | 2 | 3 | 1 |
| | | | | |
| Score | 6 | 4 | 6 | 2 |
| | | | | |
| Ranking | 3 | 2 | 3 | 1 |

Conklin & de Decker was founded in 1984 and is a leader in aviation consulting, research and education with offices in Massachusetts, Texas and Arizona. The company focuses on the analysis of performance, cost and management of both fixed- and rotary- wing aircraft, including fleet planning, cost and performance analysis, financial management, market research, aviation tax issues, and financial, tax and management seminars.

Conklin & de Decker's consulting activities have included the development of numerous fleet plans for a variety of individuals, corporations and government agencies. The fleet plans analyze payload, performance, after sales product support, cost and other factors that determine the overall effectiveness of aircraft for a particular mission. Aircraft included in the analyses have ranged from King Air 90 turboprop aircraft to Boeing 737 and 767 airliner aircraft as well as helicopters. Consulting clients have included:

- Federal Aviation Administration
- Department of Energy
- US Forest Service
- Canadian Coat Guard
- San Diego County
- National Park Service
- Boeing

The company also collects, analyzes and publishes extensive operating cost, performance and specification databases as well as maintenance management software. Its well-known Aircraft Cost Evaluator cost database and software has been published since 1984. Other databases published by the company include its Life Cycle Cost as well as its Aircraft Performance Comparator and State Tax databases and software. These databases are in use with over 2,000 customers worldwide. The company's Aircraft Cost Evaluator database is referred to by many as the industry standard and is currently used by The Wall Street Journal, Forbes, Business Jet Traveler, Twin & Turbine, Executive & VIP Jets and World Aircraft Sales when they discuss aircraft operating costs.

1006-B North Bowen * Arlington, Texas 76012
TEL 817.277.6403 * FAX 817.277.6402
www.conklindd.com